Cleanliness is key for robotic space explorers

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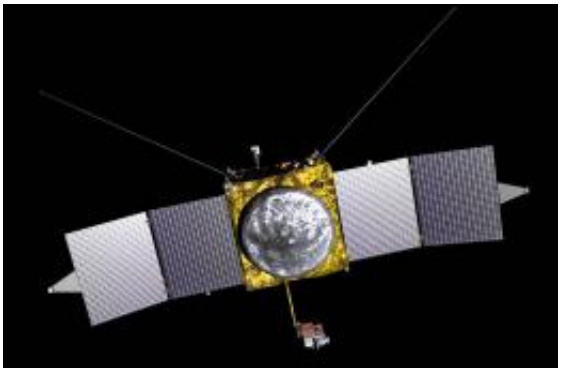

Artist's Concept of MAVEN. Credit: NASA

The concrete-floored room looks, at first glance, like little more than a garage. There is a red tool chest, its drawers labeled: "Hacksaws." "Allen wrenches." There are stepladders and vise grips. There is also, at one end of the room, a half-built spaceship, and everyone is wearing toe-to-fingertip protective suits.

"Don't. Touch. Anything."

Bruce Jakosky says the words politely but tautly, like a protective father - which, effectively, he is. Jakosky is the principal investigator behind NASA's next mission to Mars, putting him in the vanguard of an arcane niche of science: planetary protection - the science of exploring space without messing it up.

As NASA pursues the search for life in the solar system, the cleanliness of robotic explorers is crucial to avoid contaminating other worlds. Contaminants from Earth could inadvertently kill life forms on other planets just as we discover that they exist.

The decontamination of spacecraft, an obscure arm of space science, has grown in importance as NASA turned its attention to places such as Mars, Titan and Europa that have environments that are potentially conducive to life.

Jakosky's immediate concern is a $671 million probe named the Mars Atmosphere and Volatile EvolutioN orbiter, or MAVEN, which Lockheed Martin Space Systems is building south of Denver.

The craft is scheduled to launch in late 2013. Its mission is to delve into Mars' transition from a wet and warm planet to one that is dry and cold - vital research for determining whether Mars ever harbored life.

The spacecraft needs to be scrubbed so that when it impacts Mars, it is carrying no more than 500,000 spores of microbial life, so few they could fit on the head of a pin. The goal is simple, said Jakosky, a University of Colorado at Boulder professor: "Don't contaminate Mars or jeopardize your science." The trick is in the execution.

Many of the achievements that marked the onset of the Space Age meant sending astronauts into space. Today, scientists have entered a gilded age of robotic space exploration.

The rover Curiosity that landed on Mars this summer is just one in a suite of machines that have been sent to study new corners of space. Other missions will send probes to intercept an asteroid and visit a distant moon that could contain three times as much water as Earth.

It is an era fraught with anxiety for those who have the curious task of keeping space free of contamination.

"This business is not for the faint of heart," Jakosky says.

Planetary protection must operate on three levels at once.

First, spacecraft must not bring a potentially harmful level of microbes from Earth to another planet or celestial body. Scientists also must be careful not to mess up their own work - signs of extraterrestrial life could be "discovered" but could actually be false-positives born on a launch pad at Cape Canaveral.

"Taking life from Florida to Mars might give you the wrong impression about Mars," said John D. Rummel, NASA's former planetary protection officer, now a professor of biology at East Carolina University.

Most pressingly, when robots or astronauts return with samples from space, scientists must take care not to expose the Earth to alien contaminants. No one knows what would happen - probably nothing, but considering how the Earth struggles with its own invasive species, such as zebra mussels in the Great Lakes, no one wants to find out.

"We have seen on Earth the problems of transporting things from one place to another," said NASA's planetary protection officer, Catharine Conley.

The most nightmarish specter was raised in the novel "The Andromeda Strain," in which a satellite returns from space and wipes out every soul in Piedmont, Ariz. Rummel half-jokes that avoiding this scenario has its own commandment: "Thou shalt not kill taxpayers."

Outside the bay where MAVEN is being built, a bright yellow line is

painted on the floor. No sole of a shoe harboring gunk from the outside world has ever stepped on the wrong side of the line. Even getting to the door of the bay requires a serious rigmarole; you are required to stomp your real-world shoes on top of a sticky floor pad to get rid of as many germs as you can before you are permitted to even enter the dressing room.

There, workers receive a sterilized clean suit. The seam where sleeves meet rubber gloves is wrapped in duct tape, and a technician is dispatched to teach everyone how to lift one leg in the air, cover a civilian shoe with a bootee, place that leg on the other side of the yellow line and then repeat the procedure with the other.

Once dressed, the only piece of everyone's body exposed to the air is the eyes. Everyone vaguely resembles a ninja.

Inside, the level of scrutiny increases. Tools are scrubbed of microbes. Workers write on waxy paper so that particulates of ink and paper don't escape into the air. Everything is a threat - germs hiding behind silicon chips, a stray hair.

Movements are choreographed to avoid tripping, bumping or spills. Those minor transgressions could be significant if, for instance, someone were cut or their clean suit torn. "I'm on your south," one worker says as he passes behind a colleague.

Minders on the scene pursue an elusive "bioburden cleanliness." They follow workers to see where they do most of their work and quiz those who sneeze or cough about whether a cold is coming on. Connectors and assembly joints are baked to clean them off.

Amy Baker, a Lockheed Martin contractor, spends her days studying the habits of workers and the path of tools, wires and spacecraft pieces.

Where she suspects trouble, she uses cotton swabs and sterile water to test for microbes. Later, she peers at her samples under a microscope to see if she has uncovered microbes. So far, MAVEN is on track to be under its maximum microbial spore count.

The execution of planetary protection requirements means concessions big and small. MAVEN's engineers have configured the upper stage of the craft's rocket, for instance, so that it will end up in orbit around the sun for millions of years rather than crashing into Mars.

MAVEN is an orbiter, which means it is not designed to land on Mars, so it is allowed a higher threshold of microbes. But the craft will endure small atmospheric "drag" over time and eventually hit the planet in tens or hundreds of years.

The concept of planetary protection has been around for decades. During the Cold War, the United States and Russia agreed on one thing: "We mustn't mess up space," says Andy Spry, a scientist at the Jet Propulsion Laboratory in La Canada Flintridge. A 1967 United Nations treaty sealed the deal.

Planetary protectionists tend to look at space exploration through a unique prism. The Apollo program, for instance, is regarded as a great triumph - the first humans to walk on the moon. Planetary protectionists shudder at a different memory: Capsules covered in moon dust plunging into warm seawater. Scuba divers hauling out the astronauts.

"Then we let them walk across a ship before going into quarantine," Conley said. In hindsight, it didn't matter - there is no life on the moon - although scientists weren't so sure at the time.

The pendulum has also swung in the other direction. In the '70s, the Viking spacecraft cooked for 30 hours - in the same Lockheed Martin

clean room where MAVEN is being built - before being sent to Mars. The Viking craft remain the cleanest machines Americans have ever sent into space.

The sweet spot - the level of protection needed to allow for space exploration that is both aggressive and responsible - "is somewhere in the middle," Spry said.

But the middle is not easy to find. It is both impossible and impractical to fully sterilize spacecraft - and prohibitively expensive. The treaty governing planetary protection provides a general goal of avoiding "harmful contamination."

Earth's microbes were once thought unable to survive in extreme conditions. Then, scientists started finding tiny critters in some of the planet's most unpleasant places: in superheated hydrothermal vents on the floor of the ocean, encased below a quarter-mile of ice frozen for hundreds of thousands of years. Some survive clinging to nuclear fuel rods in power plants.

"These wondrous things that Earth life does is part of what makes planetary protection so tricky," said Karen Buxbaum, the Mars program planetary protection manager at JPL.

Survive in conditions like those, and it's easy to live in a clean room at a space lab. At JPL, scientists have discovered new life forms by mistake. Microbes have been discovered living in ethanol, feeding from a piece of aluminum with no other source of nutrients.

In coming years, new deep-space missions will pose new challenges. The places scientists want to visit because they might harbor life - such as the Jupiter moon of Europa, believed to have an ocean of salty water - are the very places that pose the greatest test to planetary protection.

President Barack Obama has asked NASA to send astronauts to Mars in the 2030s - a "conceptually difficult leap" for planetary protection, Buxbaum said. Human bodies contain roughly 100 trillion single-celled organisms. NASA and its European counterparts are studying what this will mean for planetary protection. What happens if an astronaut gets sick on Mars? How can scientists figure out if the sickness originated on Earth or on Mars?

If it's the latter, a wrenching decision could follow. What if another nation doesn't want to allow a sneezing astronaut back on Earth?

"Robots can be cleaned," Conley said. "Humans can't be cleaned."

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THE MISSION

What transformed a warm planet, coursing with creeks and river deltas, into a dry, cold, radiation-bathed place?

This is the puzzle for which the MAVEN spacecraft is being designed. The answer will significantly advance understanding of Mars' evolution, which is important to the central question of whether the planet ever harbored life.

MAVEN should help determine how Mars lost its atmosphere - whether it disappeared, in layman's terms, down or up.

Many scientists surmise that the carbon dioxide, water and other hallmarks of early Mars were absorbed into the planet's subsurface. "But they haven't found evidence," said Bruce Jakosky, principal investigator on the MAVEN mission. "So maybe it was lost into space. Until we know that, we can't understand how the atmosphere evolved through

time."

The device will conduct a thorough examination of Mars' upper atmosphere. The rover Curiosity, which landed in August, is to conduct a similar study of the surface atmosphere.

MAVEN is scheduled to launch in the fall and, after a 10-month trip, spend at least a year, and probably much longer, flying above the Red Planet.

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